Simultaneous estimation of precipitation and actual evapotranspiration by lysimeters - Comparison with tipping bucket and eddy covariance

S. Gebler, H.-J. Hendricks-Franssen, T. Pütz, H. Post, M. Schmidt, H. Vereecken

Forschungszentrum Jülich GmbH, Agrosphere Institute (IBG 3), Jülich, GERMANY
s.gebler@fz-juelich.de

JÜLICH FORSCHUNGSZENTRUM

TERENO TERRESTRIAL ENVIRONMENTAL OBSERVATORIES

INTRODUCTION

The estimation of precipitation (P) and actual evapotranspiration (ET_a) remains a challenge in regional scale hydrological modelling. This study compares precipitation and evapotranspiration estimates calculated with a set of six weighable lysimeters with nearby eddy covariance (EC) and tipping bucket precipitation measurements. This allows more insight into the performance and uncertainties of these methods. In addition, it allows a better interpretation of these data which are also used for model verification purposes.

STUDY SITE

The TERENO-site of Rollesbroich is located in the Eifel low mountain range.
The sub-catchment of the Rur river is a managed grassland with an extension of 31 ha and intensive high-resolution monitoring.

The mean air temperature for the site is 8°C and the average annual precipitation is ca. 1033 mm.

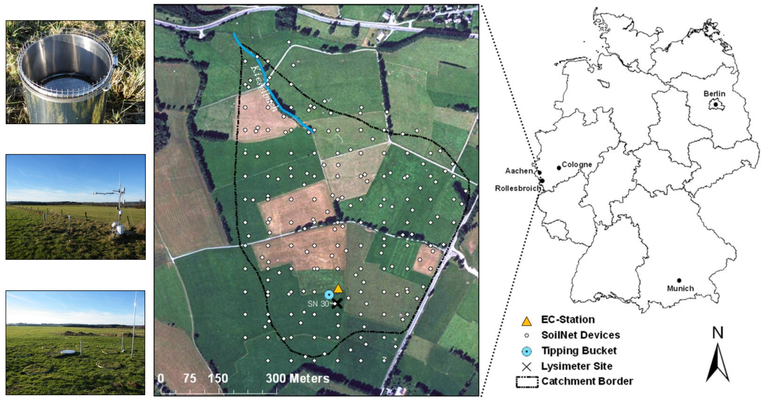

Figure 1: The Rollesbroich study site with the locations of measurement devices. The photographs show the the setup of six hexagonal arranged lysimeter devices (lower), the nearby EC tower (middle), and the tipping bucket device (upper).

MATERIALS AND METHODS

- Investigation period: January - December 2012
- Datasets: EC-data (30 min.); Lysimeter (1 min.); Tipping bucket (30 min.);

Correction of energy balance deficit (Δ EB) EC data [1]

1. Determine EBD $\Delta EB = R_{n-3h} - (G_{3h} + LE_{3h} + H_{3h} + S_{3h})$

2. Calculate evaporative fraction (EF) $EF = \frac{\overline{LE}_{7d}}{\overline{LE}_{7d} + \overline{H}_{7d}}$

3. Redistribute latent heat flux $LE_t^* = LE_t + \Delta EB_t\,(EF)$

R_n	net radiation (W m^{-2})
G	soil heat flux (W m^{-2})
LE	latent heat flux (W m^{-2})
H	sensible heat flux (W m^{-2})
S	heat storage (canopy air space, biomass, soil) (W m^{-2})

Lysimeter Data Processing

1. Automated threshold filter for outliers → **2. Smoothing of measured signal with AWAT filter** → **3. Estimation of hourly P and ET_a with smoothed signal**

Adaptive moving Window and Threshold (AWAT) filter routine [2]

- Calculates measures for signal strength and noise from moving polynomial
- Applies moving average with variable window width
- Applies variable threshold value

$$ET_a = P - L - \frac{dS_S}{dt}$$

$$P = L + \frac{dS_S}{dt}$$

Assumptions:

$P = L + \Delta S_S$; $dW > 0$

$ET_a = 0$ during P; $dW < 0$

RESULTS

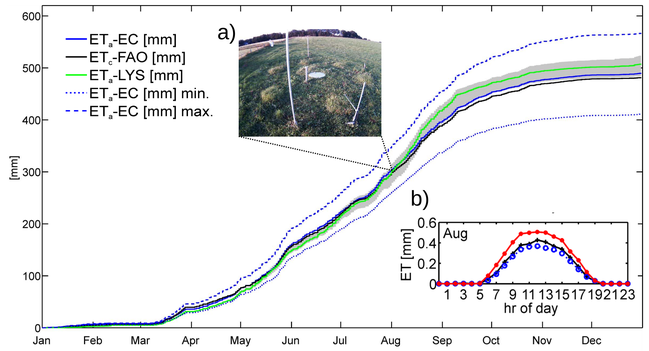

Figure 2: Cumulative ET_a-LYS, ET_a-EC (corrected according to Bowen ratio) and ET_c-FAO on hourly basis for 2012. Displayed are also ET_a-EC max. and ET_a-EC min. The area in grey shows the range of minimum and maximum cumulated ET_a for the individual lysimeters.
a) Lysimeter condition in August 2012 with grass length differing from neighborhood
b) Mean hourly rates of ET_a-LYS, ET_a-EC and ET_c calculated according FAO for August 2012

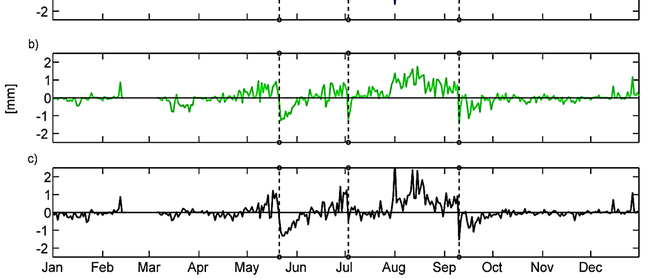

Figure 3: Differences between daily ET for 2012. Displayed are ETa-EC – ETc-FAO (a), ETa-LYS – ETc-FAO (b), and ETa-LYS – ETa-EC (c). The dashed lines indicate harvest at lysimeters.

Table 1: Monthly precipitation for lysimeter and tipping bucket (TB), and their comparison in terms of R^2, RMSE and other statistics at the Rollesbroich site for 2012. Missing data provides the percentage of hourly precipitation not available for comparison.

Month	Lysimeter Average [mm]	Min. / Max. Lysimeter [mm]	Tipping Bucket [mm]	R^2	RMSE	LYS/TB %	Missing Data %
Jan	70.9	57.6 / 79.3	94.0	0.48	0.30	75.6	11.2
Feb	36.2	31.4 / 48.9	21.1	0.13	0.32	171.6	46.1
Mar	17.3	16.2 / 18.8	5.1	0.18	0.16	339.2	16.4
Apr	72.5	71.1 / 74.6	65.3	0.90	0.09	111.0	0.0
May	90.7	89.4 / 94.1	79.3	0.99	0.09	114.4	0.0
Jun	139.9	137.5 / 143.1	134.7	0.96	0.21	103.9	0.0
Jul	148.5	146.3 / 152.2	147.0	0.95	0.28	101.0	0.0
Aug	105.7	100.4 / 109.4	84.5	0.94	0.15	125.1	0.0
Sep	36.5	23.5 / 39.2	25.6	0.58	0.13	142.6	0.0
Oct	67.5	65.7 / 69.5	66.2	0.74	0.23	102.0	13.4
Nov	55.3	52.7 / 56.9	38.3	0.84	0.08	144.4	0.0
Dec	186.0	178.5 / 194.4	121.0	0.30	0.35	153.7	0.0
SUM/MEAN	**1027.1**	**996.2 / 1037.7**	**882.1**	**0.88**	**0.47**	**116.4**	**7.1**

The precipitation differences (16.4 % more precipitation by lysimeter than with TB) were analyzed with the help of an on-site camera surveilance system and additional meteorological data (wind speed, temperature, heat fluxes):

- 2.4 % (24.5 mm) of the lysimeter precipitation is related to the occurence of dew and rime, in particular during winter and autumn. It explains 17% of precipitation difference between lysimeter and TB.
- Weather conditions with fog and drizzle contribute 5.5% (7.9 mm) to the total yearly precipitation difference between lysimeter and TB.
- Precipitation differences were also larger for snowfall events (7.9 % of total difference) with reliable values for lysimeter.
- During snow cover, lysimeters recorded erroneously large precipitation amounts, most probably related to snow bridges and snow cover. This explains 36% of the difference between lysimeter and TB, but in this case TB is more reliable than lysimeter.

CONCLUSIONS

- For 2012 the lysimeter precipitation is 16.4 % larger than precipitation measured by tipping bucket: Absolute and relative precipitation differences are larger in winter than summer.
- The true precipitation lies most probably between the lysimeter value and the tipping bucket value, as in some cases the lysimeter is more reliable (dew, fog, snowfall), but for snow cover and snow drift the lysimeter provides erroneous values.
- ET_a-EC (with EBD correction) and ET_a-LYS data are in good agreement for the considered period (3.5% difference over the year). ET_a differences are related to differences in grass length due to differing harvesting management.
- The variations of the individual lysimeters devices compared to the lysimeter mean are small (P: 3 %; ET: 8 %).

REFERENCES

[1] Kessomkiat, W., Franssen, H.-J.H., Graf, A., Vereecken, H., 2013. Estimating random errors of eddy covariance data: An extended two-tower approach. Agricultural and Forest Meteorology, 171–172(0): 203-219.
[2] Peters, A., Nehls, T., Schonsky, H., Wessolek, G., 2014. Separating precipitation and evapotranspiration from noise a new filter routine for high-resolution lysimeter data. Hydrol. Earth Syst. Sci., 18(3): 1189-1198.

ACKNOWLEDGEMENTS

We want to acknowledge TERENO-SoilCAN and TR32 contributing data for this research.